Tectonic control on crustal degassing in continental region: the role of rock fracturation

Dario Buttitta\textsuperscript{1,3}, Antonio Caracausi\textsuperscript{1}, Rocco Favara\textsuperscript{1}, Lauro Chiara Aluce\textsuperscript{2}, Maurizio Gasparo Morticelli\textsuperscript{4}, and Attilio Sulli\textsuperscript{4}

\textsuperscript{1}Istituto Nazionale di Geofisica e Vulcanologia, sezione di Palermo, Palermo, Italy (antonio.caracausi@ingv.it, rocco.favara@ingv.it)
\textsuperscript{2}Istituto Nazionale di Geofisica e Vulcanologia, Osservatorio Nazionale Terremoti, Roma, Italy (lauro.chiaraluce@ingv.it)
\textsuperscript{3}Dipartimento di Scienze, Università degli Studi della Basilicata, Potenza, Italy (dario.buttitta@unibas.it)
\textsuperscript{4}Dipartimento di Scienze della Terra e del Mare, Università di Palermo, Palermo, Italy (attilio.sulli@unipa.it, maurizio.gasparo@unipa.it)

Degassing of volatiles across the Earth crust towards the atmosphere is mainly controlled by long last diffusion. However, it can also be episodic. In fact, tectonic control of solid phase release of radiogenic helium ($^4$He) due to, e.g. fracturing, may contribute to explain variance of the continental $^4$He degassing flux over multiple time and space scales. Rock rheology have a controlling influence on a wide range of crustal-scale processes including fluid flow, tectonic deformations and seismicity. Though faults comprise a small volume of the crust, they influence the mechanical and fluid flow properties of the crust, and are mechanisms for accommodating most of the elastic strain in the crust through a variety of slip-behaviours. Helium isotopes ($^3$He, $^4$He) are useful tracers for investigating many important geological processes because helium is a stable and conservative nuclide that does not take part in any chemical or biological process. Indeed, $^4$He released from rocks in the porefluid can be used to trace the deformation of rocks in a field of stress [Bauer 2017; Torgersen and O'Donnell 1991]. In fact, a volume of rock starts to be affected by micro-fractures from since it is subjected to stress conditions exceeding about half its yield strength [Bauer, 2017]. Hence, the network of fractures evolves in a volume of rock progressively increase as a function of the evolution of deformation, improving the release of $^4$He that is trapped since its production. Consequently, $^4$He in natural fluids that outgas in a region of active tectonic can record the evolution of the field of stress and this volatile component could be used to trace changes in stress and deformation field. For the purpose of quantifying the amount of $^4$He present in the geological traps that feed the mud volcanoes of Regnano-Nirano mud volcanoes systems (Bonini et al., 2007), in the north Italy, in our study we have reconstructed the 3D geological model of the reservoirs, and proceeded to estimate the gas contained in them. Fluids emitted from these systems are thermogenic-CH\textsubscript{4} rich, which vertically migrates towards the surface. Helium is in traces and its isotopic signature (=0.01-0.02Ra, Ra is the $^3$He/$^4$He in air) shows that $^4$He is mainly produced in the crust by U-Th decay. We have found that the present $^4$He is greater than what should be available taking into account only the steady-state crustal production. Therefore, we compared the excess helium present in the reservoirs with the contribution coming
from the seismic activity of the area, which is sufficient to explain this excess. Our study highlights that an intense fracturing of a volume of rock, due to the recent seismicity below the studied area, may explain the accumulation of helium in the reservoir higher than the steady-state condition. Therefore, the effective vertical rate of fluid transport in the Earth's continental crust can be characterized by episodic events controlled by fracturing.

Bonini (2007) - JGRes Solid Earth
Torgersen & O'Donnell (1991) - GRL, vol.18
Bauer (2017) - SAND2017-9438